Models and algorithms for efficient electromobility

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Challenges and opportunities for electromobility

Challenges

- Batteries are the limiting factor for a large scale launch of electromobility because of its weight and price
- Electric vehicles (EVs) have a limited cruising range and long recharge times
- Strong peak loads occur in the power grid if a huge amount of EVs is simultaneously recharging

Opportunities

- Battery of EVs are only moved for around 5% of the day and can be used the remaining time to balance the power grid
- Buffering offers income opportunity for battery owner
- Car batteries can substitute expensive energy storage facilities

Electric vehicle used at the eE-Tour Allgäu project

Modeling for Buffering Strategies

symbol	description
$l(t)$	number of energy units charged by the EV in time slot t
$p(t)$	price for one energy unit in time slot t
g	required load of the EV
c	initial charge of the EV
m	maximum capacity of the EV
s	first time slot the EV is available for charge
e	last time slot the EV is available for charge
b	maximal charge of energy units for the EV

$$
\begin{array}{llll}
\min & \sum_{t=s}^{e} l(t)p(t) & & \\
|l(t)| & \leq & b & \forall t \\
\sum_{t=s}^{e} l(t) & \geq & g-c & \\
\sum_{k=s}^{t} l(k) & \geq & -c & \forall t \in \{s, s+1, \ldots, e\} \\
\sum_{k=s}^{t} l(k) & \leq & m & \forall t \in \{s, s+1, \ldots, e\}
\end{array}
$$

Research plan

- Determine the required amount of energy for given routes
- Minimize mobility risk by using models for the car usage
- Develop schedulers to optimize charging of the EVs
- Modeling of a fleet of EVs as competing agents
- Implementation of a simulation framework
- Evaluation with real world data from the eE-Tour Allgäu project

Progress up to date

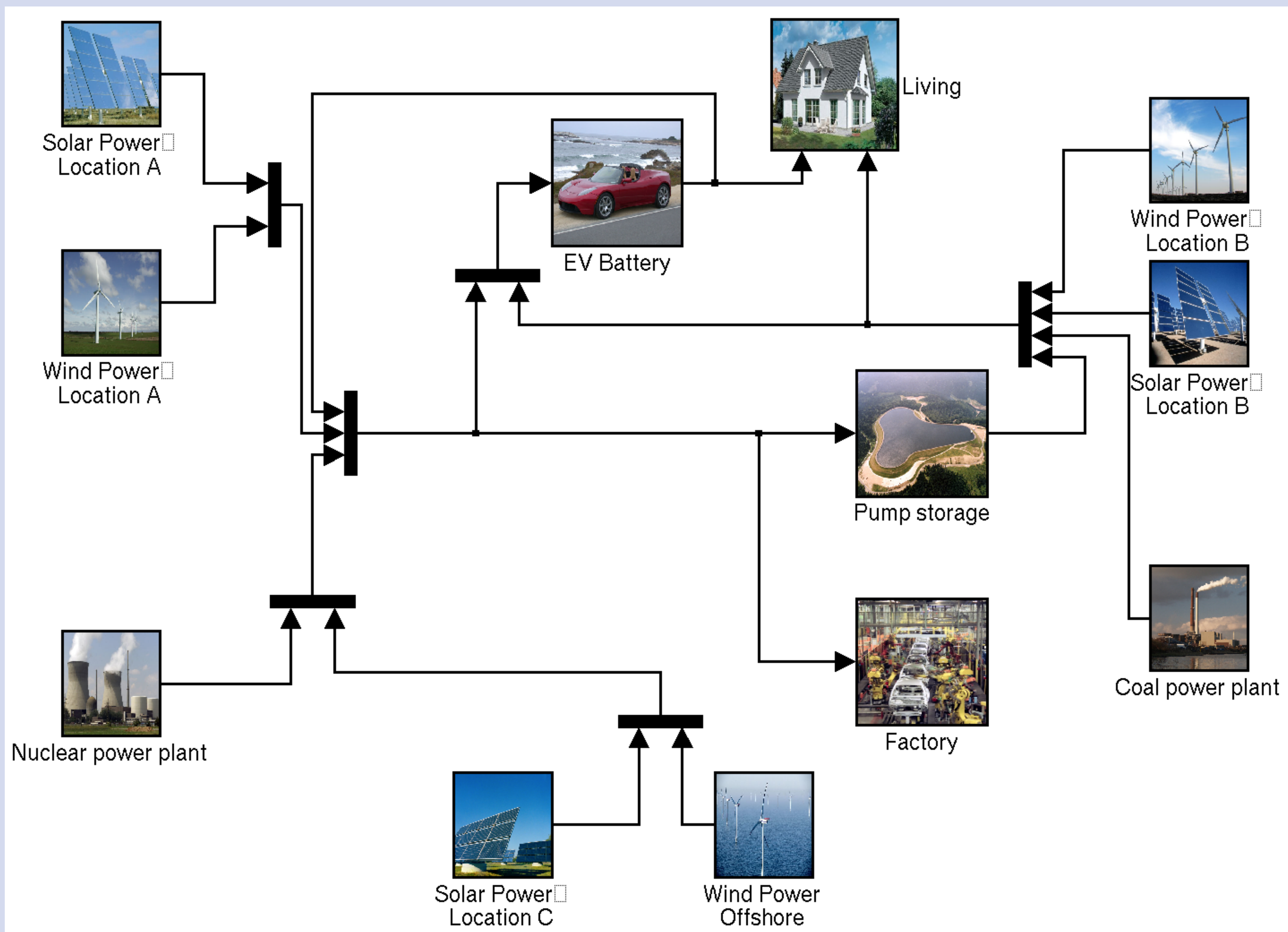
- Energetic vehicle model
- Construction of an energy graph
- Graph theoretic framework for EV routing
- Heuristic for A* with negative edges

Concept for the simulation framework

System components

- Models for batteries, energy consumption and usage
- Algorithms to predict cruising range and calculate routes
- Model of the power grid including producers, consumers and storage

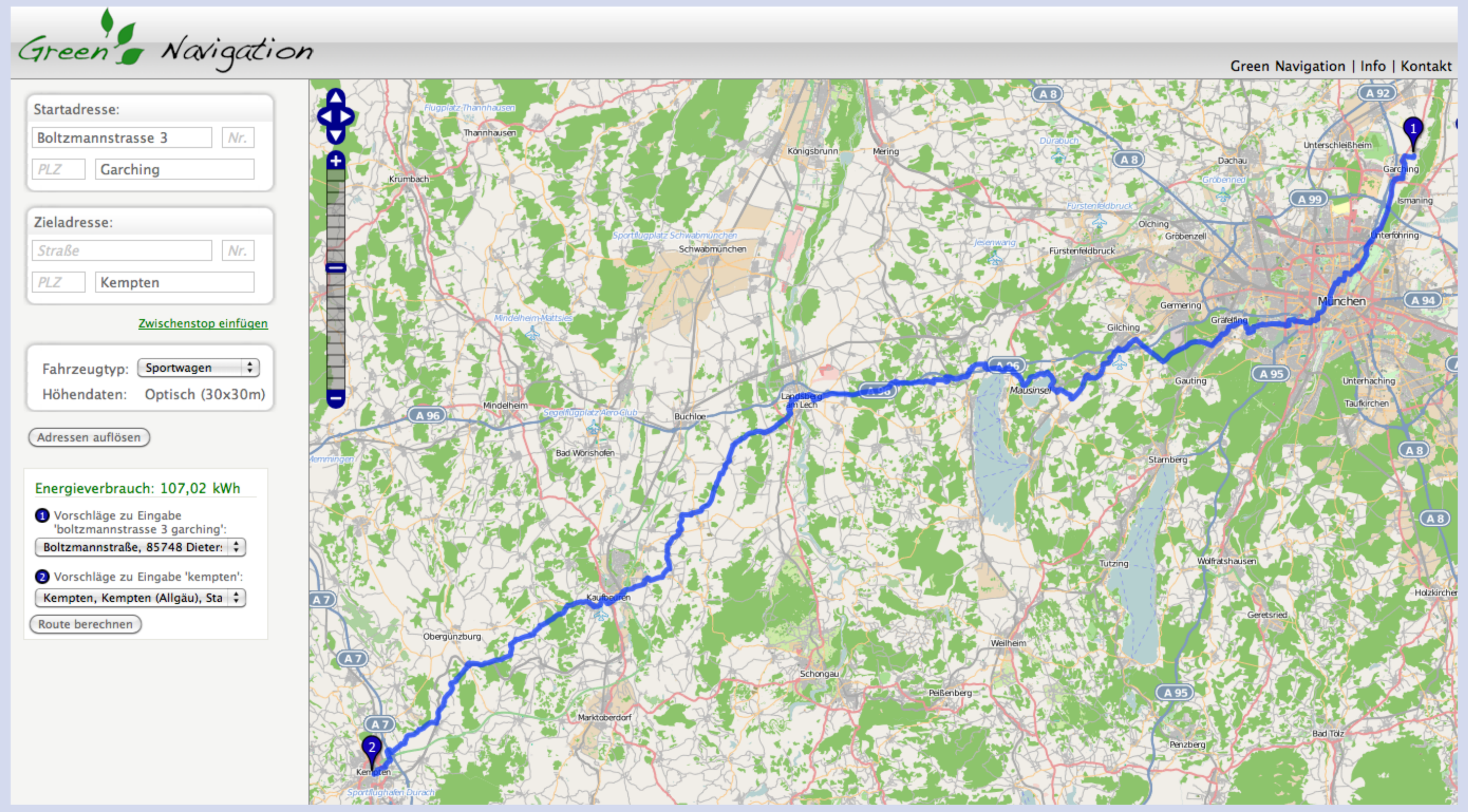
The goal is to schedule the use of the battery as energy storage to increase economic benefits while minimizing the mobility risk.



Simulink simulation framework for the charging strategy

Green Navigation

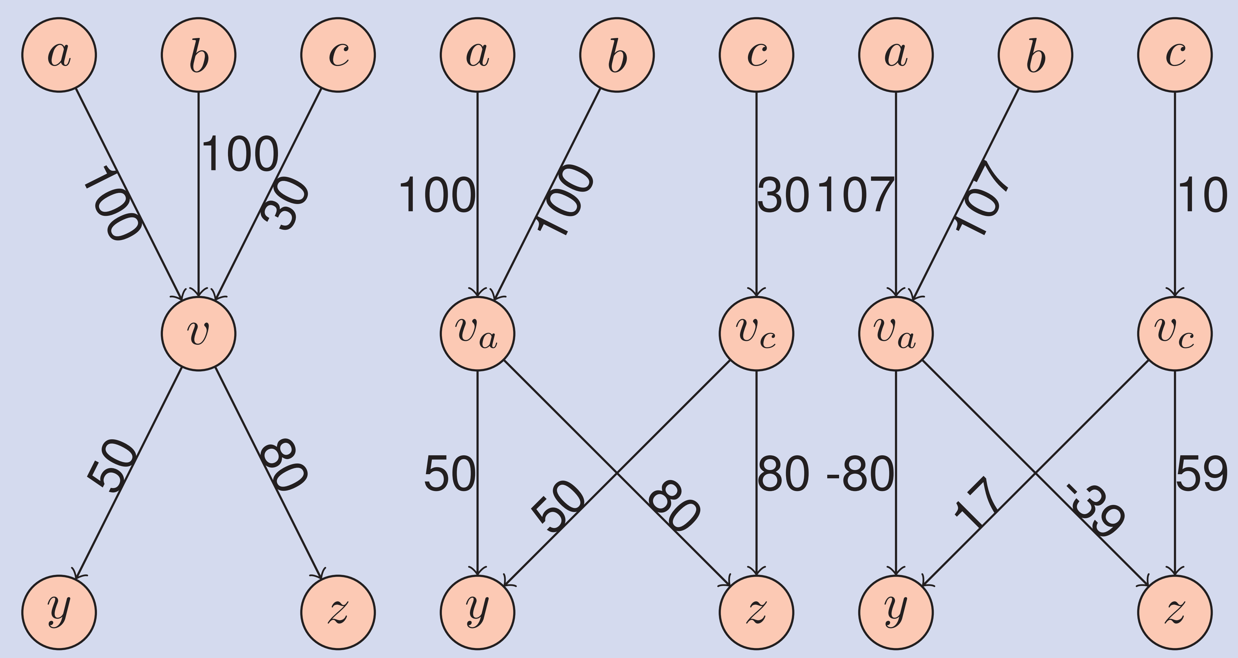
Energy efficient routing by using freely available road network data from OpenStreetMaps and altitude informations from the NASA.



Energy efficient shortest path calculated by GreenNav

From the road network to the energy graph

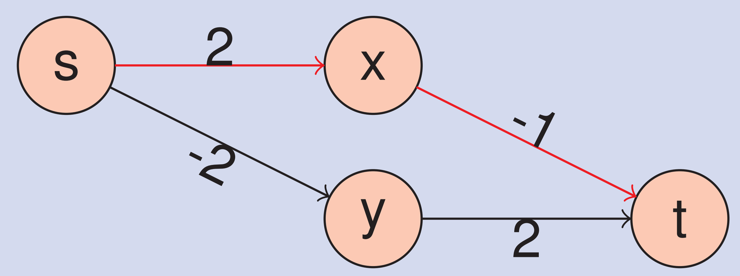
The energy graph represents for each road section its estimated energy consumption. The calculation considers road network, altitude values, the battery and the vehicle model.



The left graph represents a junction in a road network, followed by its topological expansion and finally the energy graph. The expansion is necessary to account for different velocities and consequently different kinetic energy values of predecessors of a node.

Routing with energy constraints

The energy graph has special a ability due to the law of conservation of energy and the underlying road network (A* heuristic)



Fully charged battery:
Route $s \to x \to t$: costs 1
Route $s \to y \to t$: costs 2